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ORTHOGONAL COMPLEX SPREADING METHOD AND APPARATUS FOR MULTIPLE CHANNELS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an improved orthogonal complex spreading method and apparatus for multiple channels. The invention is capable of the following: decreasing a peak power-to-average power ratio by introducing an orthogonal complex spreading structure and spreading input signals using a spreading code; implementing a structure capable of spreading complex output signals using a spreading code by adapting a permuted orthogonal complex spreading structure for a complex-type multi-channel input signal with respect to the summed values; and decreasing a phase dependency of an interference based on a multipath component (when there is an one chip difference) of a self signal, which is a problem that is not overcome by a permuted complex spreading modulation method, nor by a combination of an orthogonal Hadamard sequence.

2. Description of the Prior Art

In the area of mobile communication systems, it is well known in the art that linear and non-linear distortions affect power amplifiers. The statistical characteristic of

a peak power-to-average power ratio has a predetermined interrelationship for non-linear distortion.

The third order non-linear distortion, which is one of the factors affecting the power amplifier, causes an inter-modulation problem in an adjacent frequency channel. The inter-modulation problem created by a high peak amplitude, which increases the adjacent channel power (ACP), so that there is a predetermined limit for selecting the amplifier. In particular, the Code Division Multiple Access (CDMA) system requires a very strict condition with respect to linearity of a power amplifier. Therefore, the above-described condition is a very important factor.

In accordance with International Standards 97 and 98, the FCC stipulates a condition on the adjacent channel power (ACP). In order to satisfy the above-described condition, the bias of the Radio Frequency (RF) power amplifier has to be limited.

According to the current IMT-2000 system standard recommendation, a plurality of CDMA channels are recommended. In case a plurality of channels are provided, the peak power-to-average power ratio is considered an important factor for increasing the efficiency of the modulation method.

The IMT-2000, which is a third generation mobile communication system, has received a lot of attention as the next generation communication system following the digital cellular system, personal communication system, and etc. The IMT-2000 will be commercially available as a wireless communication system, which has a high capacity and performance for supporting various multimedia services and international roaming services, etc.

Many countries have proposed utilizing IMT-2000 systems that would require high data transmission rates for internet service or electronic commercial activity. This is directly related to the power efficiency of a RF amplifier.

The IMT-2000 modulation method based on CDMA technology is classified as a pilot channel and symbol method. The pilot channel method is directed to the CDMA ONE introduced in North America. The pilot symbol method is directed to the NTT-DOCOMO and ARIB proposal introduced in Japan and to the FMA2 proposal introduced in Europe.

Fig. 1 illustrates a prior art complex spreading method based on a CDMA ONE method.

The CDMA ONE is implemented by using a complex spreading method. The pilot channel and the fundamental channel spread by a Walsh code 1 are summed thereby forming in-phase information. The supplemental channel spread by a Walsh code 2 and the control channel spread by a Walsh code 3 are also summed thereby forming quadrature-phase information. In addition, the in-phase and quadrature-phase information are complex-spread by PN codes.

As shown, the signals from a fundamental channel 1A, a supplemental channel 1B, and a control channel 1C are multiplied by Walsh codes $W_{4,1}$, $W_{4,2}$ and $W_{4,3}$, which is performed by each multiplier (20A, 20B and 20C) of multiplication unit 20 through a signal-mapping unit 10. The pilot signal and the signals multiplied by the Walsh codes are respectively multiplied by channel gains A0, A1, A2 and A3 in channel gain multiplication unit 30.

In a summing unit 40, the pilot signal and the fundamental channel signal are summed by a first adder 40a thereby obtaining in-phase information. Additionally, the supplemental channel signal and the control channel signal are summed by a second adder 40b thereby obtaining quadrature phase information.

The in-phase and quadrature-phase information are then multiplied by ~~a~~ PN1 and PN2 code by spreading unit 50. The identical phase information multiplied by the PN2 code is then subtracted by the in-phase information multiplied by the PN2 code is outputted as an I channel signal. The quadrature-phase information multiplied by the PN1 code and the in-phase information multiplied by the PN2 code are summed and then outputted through as a Q channel signal a delay unit 60.

Fig. 2A is a view illustrating a constellation of signals in a phase domain before pulse shaping in a prior art CDMA ONE method and Fig. 2B is a view illustrating a constellation of signals in a phase domain after shaping in prior art CDMA ONE method.

In the CDMA ONE, the left and right information, namely, the in-phase information (I channel) and the upper and lower information, namely, the quadrature-phase information (Q channel) pass through the actual pulse-shaping filter thereby causing a peak power.

In view of the crest factor and the statistical distribution of the power amplitude, the peak power is generated in a vertical direction so that the problems such as irregular spreading of code and crosstalk occur.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an orthogonal complex spreading method and apparatus for multiple channels that overcomes the aforementioned problems encountered in the prior art.

The peak power-to-average power ratio is important in IMT-2000 system since the CDMA system requires a strict condition for linearity of a power amplifier. In particular, the IMT-2000 system provides multiple channels, which transmit signals simultaneously, and the peak power-to-average power ratio is related to the efficiency of the modulation method.

It is another object of the present invention to provide an orthogonal complex spreading method and apparatus for multiple channels, which have an excellent power efficiency compared with the complex spreading methods introduced in the CDMA-ONE of the United States and the W-CDMA. Additionally, the invention is capable of resolving a power unbalance problem of an in-phase and quadrature-phase channel as well as the complex spreading method.

It is still another object of the present invention to provide an orthogonal complex spreading method and apparatus for multiple channels, which is capable of maintaining a stable low peak power-to-average power ratio.

Additionally, in the present invention a spreading operation is implemented as follows: multiplying predetermined channel data among data of a multichannel by an orthogonal Hadamard sequence and a gain; multiplying data of another channel by an orthogonal Hadamard sequence and a gain; summing the information of the two channels

in complex type; multiplying the summed information of the complex type by the orthogonal Hadamard sequence of the orthogonal type; obtaining a complex type; summing a plurality of channel information of the complex type in the above-described manner; and multiplying the information of the complex type of the multichannel by a spreading code sequence.

Furthermore, it is an object of the present invention to decrease the probability that the power drops to zero by doing the following: preventing the FIR filter input state from exceeding 90° in an earlier sample state; increasing the power efficiency and decreasing the consumption of bias power for a back-off of the power amplifier; and saving the power of a battery.

It is still another object of the present invention to provide an orthogonal complex spreading method and apparatus for a multichannel, which is capable of implementing a Permuted Orthogonal Complex QPSK (POCQPSK) which is another modulation method that has a power efficiency similar with the Orthogonal Complex QPSK (OCQPSK).

In order to achieve the above objects, there is an orthogonal complex spreading method that is provided for a multichannel which includes the following steps: complex-summing $\alpha_{n1}W_{M,n1}X_{n1}$, which is obtained by multiplying an orthogonal Hadamard sequence $W_{M,n1}$ by a first set of data of X_{n1} of a n-th block, and $\alpha_{n2}W_{M,n2}X_{n2}$, which is obtained by multiplying an orthogonal Hadamard sequence $W_{M,n2}$ by a second set of data of X_{n2} of a n-th block; complex-multiplying $\alpha_{n1}W_{M,n1}X_{n1}+j\alpha_{n2}W_{M,n2}X_{n2}$, which is summed in the complex type, and $W_{M,n3}+jW_{M,n4}$ of the complex type using a complex multiplier and outputting in-phase and quadrature-phase information; summing only in-phase information outputted from a plurality of blocks and only quadrature-phase information outputted therefrom; and spreading the same using a spreading code.

In order to achieve the above objects, there is provided an orthogonal complex spreading apparatus according to a one embodiment of the present invention which includes the following: a plurality of complex multiplication blocks for distributing the data of the multichannel and complex-multiplying $\alpha_{n1}W_{M,n1}X_{n1}+j\alpha_{n2}W_{M,n2}X_{n2}$ in which $\alpha_{n1}W_{M,n1}X_{n1}$ is obtained by multiplying the orthogonal Hadamard sequence $W_{M,n1}$ with the first set of data of X_{n1} of the n-th block and the gain α_{n1} and $\alpha_{n2}W_{M,n2}X_{n2}$, which is obtained by multiplying the orthogonal Hadamard sequence $W_{M,n2}$ with the second set of data of X_{n2} of the n-th block and the gain α_{n2} and $W_{M,n3}+W_{M,n4}$ using the complex multiplier; a summing unit for summing only the in-phase information outputted from each block of the plurality of the complex multiplication blocks and summing only the quadrature-phase information; and a spreading unit for multiplying the in-phase and quadrature-phase information summed by the summing unit with the spreading code and outputting an I channel and a Q channel.

In order to achieve the above objects, there is provided an orthogonal complex spreading apparatus according to another embodiment of the present invention, which includes the following: first and second Hadamard sequence multipliers for allocating the multichannel to a predetermined number of channels, splitting the same into two groups and outputting $\alpha_{n1}W_{M,n1}X_{n1}$, which is obtained by multiplying the data X_{n1} of each channel by the gain α_{n1} and the orthogonal Hadamard sequence $W_{M,n1}$; a first adder for outputting $\sum_{n=1}^{K}(\alpha_{n1}W_{M,n1}X_{n1})$, which is obtained by summing the output signals from the first Hadamard sequence multiplier; a second adder for outputting $\sum_{n=1}^{K}(\alpha_{n2}W_{M,n2}X_{n2})$, which is obtained by summing the output signals from the second Hadamard sequence multiplier; a complex multiplier for receiving the output signal from

the first and second adder in the complex form of

$$\sum_{n=1}^{K} (\alpha_{n1} W_{M,n1} X_{n1} + j\alpha_{n2} W_{M,n2} X_{n2})$$ and complex-multiplying $W_{M,I}+jPW_{M,Q}$ where n=1

consists of the orthogonal Hadamard code $W_{M,I}$ and the permuted orthogonal Hadamard code $PW_{M,Q}$ where $W_{M,Q}$ and a predetermined sequence P are complex-multiplied; a spreading unit for multiplying the output signal from the complex multiplier by the spreading code; a filter for filtering the output signal from the spreading unit; and a modulator for multiplying and modulating the modulation carrier wave, summing the in-phase and quadrature-phase signal and outputting a modulation signal of the real number.

Additional advantages, objects and other features of the invention will be set forth in the description which follows and will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given below and the accompanying drawings, which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

Fig. 1 is a block diagram illustrating a prior art multichannel complex spreading method of a CDMA ONE method;

Fig. 2A is a view illustrating a constellation of signals in a phase domain before pulse shaping in a prior art CDMA ONE method;

Fig. 2B is a view illustrating a constellation of signals in a phase domain after pulse shaping in a prior art CDMA ONE method;

Fig. 4 is a block diagram illustrating a multi-channel orthogonal complex spreading apparatus in accordance with one embodiment of the present invention;

Fig. 5A is a circuit diagram illustrating the complex multiplier of Fig. 4;

Fig. 5B is a circuit diagram illustrating the summing unit and spreading unit of Fig. 4;

Fig. 5C is a circuit diagram illustrating another embodiment of the spreading unit of Fig. 4;

Fig. 5D is a circuit diagram illustrating the filter and modulator of Fig.4;

Fig. 6A is a view illustrating a constellation of signals in a phase domain before pulse shaping in an OCQPSK according to the present invention;

Fig. 6B is a view illustrating a constellation of signals in a phase domain after pulse shaping in an OCQPSK in accordance with the present invention;

Fig. 7 is a view illustrating a statistical distribution characteristic of power peak occurrences with respect to an average power between the prior art and the present invention;

Fig. 8 illustrates an example of an orthogonal Hadamard sequence in accordance with the present invention;

Fig. 9 is a circuit diagram illustrating a multichannel permuted orthogonal complex spreading apparatus in accordance with another embodiment of the present invention;

Fig. 10 is a circuit diagram illustrating the complex multiplier of Fig. 8;

Fig. 11 is a circuit diagram illustrating a multichannel permuted orthogonal

complex spreading apparatus with two input channels in accordance with the present invention;

Fig. 12 is a circuit diagram illustrating a multichannel permuted orthogonal complex spreading apparatus with three input channels in accordance with the present invention;

Fig. 13A is a circuit diagram illustrating a multichannel permuted orthogonal complex spreading apparatus for a QPSK having a high transmission rate with the present invention;

Fig. 13B is a circuit diagram illustrating a multichannel permuted orthogonal complex spreading apparatus with four input channels in accordance with the present invention;

Fig. 14A is a circuit diagram illustrating a multichannel permuted orthogonal complex spreading apparatus for a multimedia service in accordance with the present invention;

Fig. 14B is a circuit diagram illustrating a multichannel permuted orthogonal complex spreading apparatus with five input channels in accordance with the present invention;

Fig. 15A is a phase trajectory view of an OCQPSK according to the present invention;

Fig. 15B is a phase trajectory view of a POCQPSK according to the present invention; and

Fig. 15C is a phase trajectory view of a prior art complex spreading method.

DETAILED DESCRIPTION OF THE INVENTION

The complex summing unit and complex multiplier, according to the present invention, will be explained with reference to the accompanying drawings. In the present invention, assuming that two complex number (a+jb) and (c+jd) are used, where a, b, c and d represent predetermined real numbers, a complex summing unit outputs (a+c)+j(b+d) and a complex multiplier outputs ((axc)-(bxd))+j((bxc)+(axd)). The following items are defined for the invention: a spreading code sequence is defined as SC; information data is defined as X_{n1} and X_{n2}; a gain constant is defined as α_{n1} and α_{n2}; and an orthogonal Hadamard sequence is defined as $W_{M,n1}$, $W_{M,n2}$, $W_{M,n3}$, $W_{M,n4}$, $W_{M,I}$, $W_{M,Q}$, where M represents a MxM Hadamard matrix and n1, n2, n3 and n4 represent an index of predetermined vectors of the Hadamard matrix. For example, n3 represents a Hadamard vector, wherein $W_{M,n3}$ is a third vector value described in n-th block 100n shown in Fig. 4.

The data X_{n1}, X_{n2}, $W_{M,n1}$, $W_{M,n2}$, $W_{M,n3}$, $W_{M,n4}$, $W_{M,I}$, ~~and~~ $W_{M,Q}$ and spreading sequence SC are combined data consisting of +1 or −1. α_{n1} and α_{n2} are real numbers.

Fig. 4 is a block diagram illustrating a multichannel orthogonal complex spreading apparatus, in accordance with one embodiment of the present invention.

As shown therein, there is provided a plurality of complex multipliers 100 through 100n. In a complex multiplier 100n, data X_{n1} of a predetermined channel is multiplied by a gain α_{n1} and an orthogonal Hadamard sequence $W_{M,n1}$ and data X_{n2} of another channel is multiplied by a gain α_{n2} and an orthogonal Hadamard sequence $W_{M,n2}$. The data from both channels are complex-summed and then the complex orthogonal Hadamard sequence $W_{M,n3} + jW_{M,n4}$ is multiplied by the complex-summed data $\alpha_{n1}W_{M,n1}X_{n1} + j\alpha_{n2}W_{M,n2}X_{n2}$

and the data of the other complex-multipliers are obtained in the same manner as described above. The summing unit 200 sums the output signals from complex multipliers 100 through 100n. The spreading unit 300 multiplies the output signal from the summing unit 200 with a predetermined SC, thereby spreading the signal. A pulse-shaping filter 400 filters the data spread by the spreading unit 300. A modulation wave multiplier 500 multiplies the output signal from the filter 400 with a modulation carrier wave $e^{2\pi fct}$.

As shown in Fig. 4, the first complex multiplier 100 complex-sums $\alpha_{11}W_{M,11}X_{11}$, obtained by multiplying the orthogonal Hadamard sequence $W_{M,11}$ with the data X_{11} of one channel and the gain α_{11}, and $\alpha_{12}W_{M,12}X_{12}$, obtained by multiplying the orthogonal Hadamard sequence $W_{M,12}$ with the data X_{12} of another channel and the gain α_{12}. The $\alpha_{11}W_{M,11}X_{11} + j\alpha_{12}W_{M,12}X_{12}$ is then multiplied by the complex-type orthogonal sequence $W_{M,13}X_{11}+jW_{M,14}$ at the complex multiplier 111.

In addition, the n-th complex multiplier 100n complex-sums $\alpha_{n1}W_{M,n1}X_{n1}$, obtained by multiplying the orthogonal Hadamard sequence $W_{M,n1}$ with the data X_{n1} of another channel and the gain α_{n1}, and $\alpha_{n2}W_{M,n2}X_{n2}$, obtained by multiplying the orthogonal Hadamard sequence $W_{M,n2}$ with the data X_{n2} of another channel and the gain α_{n2}. The $\alpha_{n1}W_{M,n1}X_{n1} + j\alpha_{n2}W_{M,n2}X_{n2}$ is complex-multiplied by the complex-type orthogonal sequence $W_{M,n3}X_{11}+jW_{M,n4}$ at the complex multiplier 100n.

The complex multiplication data outputted from the n-number of the complex multipliers are summed at the summing unit 200, and the spreading code SC is multiplied and spread by using the spreading unit 300. The spread data is filtered at the pulse-shaping

filter 600 and then multiplied by the modulation carried $e^{j2\pi fct}$ at the multiplier 700. The modulated signal is then processed by the function Re{*} 70 to thereby output the real data s(t) 80 through the antenna. Here, Re{*} 70 represents a function through which a predetermined complex number is processed as a real value.

The above-described function will be explained as follows:

$$\left(\sum_{n=1}^{K}((\alpha_{n1}W_{M,n1}X_{n1}+j\alpha_{n2}W_{M,n2}X_{n2})\times(W_{M,n3}+jW_{M,n4}))\right)\times SC$$

K represents a predetermined integer greater than or equal to 1; and n represents an integer greater than or equal to 1 and less than K and is identical with the index of each complex multiplier.

In Fig. 5A, the complex multiplier includes the following: a first multiplier 101; a second multiplier 102; a third multiplier 103; a fourth multiplier 104; fifth and sixth multipliers 105 and 106; seventh and eighth multipliers 107 and 108; a first adder 109; and a second adder 110.

The first and second multipliers 101 and 102 multiply the data X_{11} by the orthogonal Hadamard sequence $W_{M,11}$ and the gain α_{11} thereby obtaining $\alpha_{11}W_{M,11}X_{11}$(=a). In addition, the third and fourth multipliers 103 and 104 multiply the orthogonal Hadamard sequence $W_{M,12}$ and the gain α_{12} thereby obtaining $\alpha_{12}W_{M,12}X_{12}$(=b). The fifth and sixth multipliers 105 and 106 multiply $\alpha_{11}W_{M,11}X_{11}$(=a) and $\alpha_{12}W_{M,12}X_{12}$(=b) by the orthogonal Hadamard sequence $W_{M,13}$(=c), respectively, for thereby obtaining $\alpha_{11}W_{M,11}X_{11}W_{M,13}$(=ac) and $\alpha_{12}W_{M,12}X_{12}W_{M,13}$(=bc). Additionally, the fifth and sixth multipliers 105 and 106 multiply $\alpha_{11}W_{M,11}X_{11}$(=a) and $\alpha_{12}W_{M,12}X_{12}$(=b) by the orthogonal

Hadamard sequence $W_{M,14}$(=d) thereby obtaining $\alpha_{11}W_{M,11}X_{11}W_{M,14}$(=ad) and $\alpha_{12}W_{M,12}X_{12}W_{M,14}$(=bd). Thus, $\alpha_{12}W_{M,12}X_{12}W_{M,14}$ is subtracted from $\alpha_{11}W_{M,11}X_{11}W_{M,13}$. The second adder 110 then computes $(\alpha_{11}W_{M,11}X_{11}W_{M,14})+(\alpha_{12}W_{M,12}X_{12}W_{M,13})$ (ad+bc). Specifically, $\alpha_{11}W_{M,11}X_{11}W_{M,14}$(=ad) is added with $\alpha_{12}W_{M,12}X_{12}W_{M,13}$(=bc).

Referring back to Fig. 4, the first complex multiplier 100 is configured identically with the n-th complex multiplier 100n. The expression "(a+jb)(c+jd) = ac-bd+j(bc+ad)" is obtained assuming that $\alpha_{11}W_{M,11}X_{11}$ is "a", $\alpha_{12}W_{M,12}X_{12}$ is "b", the orthogonal Hadamard sequence $W_{M,13}$ is "c", and the orthogonal Hadamard sequence $W_{M,14}$ is "d". Therefore, the signal outputted from the first complex multiplier 100 becomes the in-phase information "ac-bd" and the quadrature-phase information "bc+ad".

In addition, Fig. 5B is a circuit diagram illustrating the summing and spreading unit of Fig. 4 and Fig. 5C is a circuit diagram illustrating another embodiment of the spreading unit of Fig. 4.

As shown therein, the summing unit 200 includes a first summing unit 210 for summing the in-phase information A_1(=(ac-bd)) outputted from a plurality of complex multipliers and a second summing unit 220 for summing the quadrature-phase information B_1(=(bc+ad)) outputted from the complex multipliers.

The spreading unit 300 includes first and second multipliers 301 and 302 for multiplying the output signals from the first adder 210 and the second adder 220 of the summing unit 200 by the SC. In other words, the in-phase and quadrature-phase signals are spread by the same SC.

In Fig. 5C, the spreading unit 300 includes the following: first and second multipliers 310 and 320; third and fourth multipliers 330 and 340; a first adder 350; and a second adder 360.

In the summing unit 200, the in-phase and quadrature-phase information of the n-number of the complex multipliers are summed by the first and second adders 210 and 220. In the spreading unit 300, the in-phase value (g) and the quadrature phase value (h) from the summing unit 200 are multiplied by the first spreading code SC1 (l) by the first and second multipliers 310 and 320 thereby obtaining gl and hl, in addition, the in-phase value (g) and the quadrature phase value (h) from the summing unit 200 are multiplied by the second spreading code SC2(m) by the third and fourth multipliers 330 and 340 thereby obtaining gm and hm. The first adder 350 computes gl-hm, in which hm is subtracted from gl, and the second adder 360 computes hl+gm, in which hl is added by gm.

In Fig. 5D, the filter 400 includes first and second pulse shaping filters 410 and 420 for filtering the I channel signal, which is the in-phase information shown in Fig. 5B and 5C, and the Q channel signal, which is the quadrature phase information signal. The modulation unit 500 includes the following: first and second multipliers 510 and 520 for multiplying the output signals from the first and second pulse shaping filters 410 and 420 by $\cos(2\pi f_c t)$ and $\sin(2\pi f_c t)$; and an adder 530 for summing the output signals from the first and second multipliers 510 and 520 and outputting a modulation data S(t).

In the present invention, the orthogonal Hadamard sequences may be replaced by a Walsh code or other orthogonal code.

Fig. 8 illustrates a 8x8 Hadamard matrix as an example of the Hadamard or Walsh code. The sequence vector of a k-th column or row is set to W_{k-1}. In this case, if k is 1, W_{k-1} represents W_0 of the column or row and if k is 5, W_{k-1} represents W_4 of the column or row.

In order to enhance the efficiency of the present invention, the orthogonal Hadamard sequence by which multiplies each channel data is multiplied, is determined as

follows. In the MxM Hadamard matrix, the sequence vector of the k-th column or row is set to W_{k-1}. It can be set that $W_{M,n1}=W_0, W_{M,n2}=W_{2p}$ (where p represents a predetermined number of (M/2)-1), $W_{M,n3}=W_{2n-2}, W_{M,n4}=W_{2n-1}$(where n represents the number of n-th blocks) so that $\alpha_{n1}W_0X_{n1}+j\alpha_{n2}W_{2p}X_{n2}$ is complex-multiplied by $W_{2n-2}+jW_{2n-1}$.

In Fig. 4, if only the first complex multipliers are used, then, only two channels are complex-multiplied, so that it can be determined that $W_{M,11}=W_0$, $W_{M,12}=W_2$, or $W_{M,12}=W_4$, $W_{M,13}=W_0$, and $W_{M,14}=W_1$, so that $\alpha_{11}W_0X_{11}+j\alpha_{12}W_2X_{12}$ or $\alpha_{11}W_0X_{11}+j\alpha_{12}W_4X_{12}$ is complex-multiplied by W_0+jW_1.

If the two complex multipliers are used in Fig. 4 it can be determined that $W_{M,21}=W_0$, $W_{M,22}=W_4$, $W_{M,23}=W_2$ and $W_{M,24}=W_3$, so that $\alpha_{21}W_0X_{21}+j\alpha_{22}W_4X_{22}$ is complex-multiplied by W_2+jW_3.

Additionally, if spreading is implemented by using the SC, as shown in Fig. 5, one spreading code may be used. However, two spreading codes SC1 and SC2 may also be used, as shown in Fig. 5C.

In order to achieve the objects of the present invention, the combined orthogonal Hadamard sequence may be used instead of the orthogonal Hadamard sequence thereby removing phase dependency based on the interference generated in the multiple paths of self-signal and the interference other users.

If the sequence vector of the k-th column or row is set to W_{k-1} in the MxM (M=8) Hadamard matrix, and the sequence vector of the m-th column or row is set to W_m, the combined orthogonal Hadamard vector $W_{k-1/m-1}$ is constructed by taking the first M/2 or the last M/2 from the vector W_{k-1}, and the last M/2 or the first M/2 from W_{m-1}. In the case of two channels, for example, it is possible to determine $W_{M,11}=W_0$, $W_{M,12}=W_{4/1}$, $W_{M,1}=W_0$, $W_{M,Q}=W_{1/4}$, so that $\alpha_{11}W_0X_{11}+j\alpha_{12}W_{4/1}X_{12}$ is complex-multiplied by $W_0+jPW_{1/4}$.

In the case of three channels, the summed value of $\alpha_{11}W_0X_{11}+j\alpha_{12}W_{4/1}X_{12}$ and $\alpha_{21}W_2X_{21}$ are complex-multiplied by $W_0+jPW_{1/4}$ based on $W_{M,11}=W_0$, $W_{M,12}=W_{4/1}$, $W_{M,21}=W_2$, and $W_{M,I}=W_0$, $W_{M,Q}=W_{1/4}$.

In addition, in the case of two channels, to the summed value of $\alpha_{11}W_0X_{11}+j\alpha_{12}W_{2/1}X_{12}$ are complex-multiplied by $W_0+jPW_{1/2}$ based on $W_{M,11}=W_0$, $W_{M,12}=W_{2/1}$, and $W_{M,I}=W_0$, $W_{M,Q}=W_{1/2}$.

In addition, in the case of three channels, the summed value of $\alpha_{11}W_0X_{11}+j\alpha_{12}W_{2/1}X_{12}$ and $\alpha_{21}W_4X_{21}$ are complex-multiplied by $W_0+jPW_{1/2}$ based on $W_{M,11}=W_0$, $W_{M,12}=W_{2/1}$, $W_{M,21}=W_4$, and $W_{M,I}=W_0$, $W_{M,Q}=W_{1/2}$.

Therefore, the cases of two and three channels have been explained. The two and three channels may be selectively used in accordance with the difference of the impulse response characteristic of the pulse shaping band pass filter.

Fig. 6A is a view illustrating a constellation of signals in a phase domain before pulse shaping in the OCQPSK in accordance with the present invention. Fig. 6B is a view of a constellation of signals in a phase domain after pulse shaping in an OCQPSK of Fig. 6A. Fig. 7 is a view illustrating a statistical distribution characteristic of power peak occurrences with respect to an average power between the prior art CDMA ONE and the present invention. The embodiment of Fig. 6A is similar to Fig. 2A. However, there is a difference in the signals after the pulse shaping. In Fig. 6B, the range of the upper and lower information (Q channel) and the left and right information (I channel) are saturated to their respective limits. This causes the difference of the statistical distribution of the peak power-to-average power.

Fig. 7 illustrates the peak power-to-average power ratio based on the result of the actual simulation between the present invention and the prior art. In order to provide

identical conditions, the power level of the control or signal channel is set to the same the same power level of the communication channel (Fundamental channel, Supplemental channel; or In-phase channel, the Quadrature channel). Additionally, the power level of the pilot channel is set lower than the power level of the communication channel by 4dB. In the above-described condition, the statistical distributions of the peak power-to-average power are compared.

In case of OCQPSK, in accordance with the present invention, the comparison is implemented by using the first complex multiplier 100 and the n-th complex multiplier 100n shown in Fig. 4. The first block 100 is implemented based on $W_{M,11}=W_0$, $W_{M,12}=W_4$, $W_{M,13}=W_0$, and $W_{M,14}=W_1$, and the n-th block 100n is implemented based on $W_{M,n1}=W_0$, $W_{M,n2}=W_4$, $W_{M,n3}=W_2$, and $W_{M,n4}=W_3$. In addition, the SCI is used as spreading code, and the SC2 is not used.

In the case of OCQPSK, the probability that the instantaneous power exceeds the average power value (0 dB) by 4 dB is 0.03%, and in the case of CDMA ONE, it is 0.9%. Therefore, the present invention has a very excellent characteristic with respect to the power efficiency and as a new modulation method, it reduces the crosstalk interference problem.

Fig. 9 illustrates a POCQPSK in accordance with the present invention. As shown therein, one or a plurality of channels are combined and complex-multiplied by the permuted orthogonal Hadamard code and then are spread by the spreading code.

In Fig. 9, the following items are provided: first and second Hadamard sequence multipliers 600 and 700 for respectively having a predetermined number of channels allocated and outputting $\alpha_{n1}W_{M,n1}X_{n1}$, which is obtained by multiplying the data X_{n1} of each channel by the gain α_{n1} and the orthogonal Hadamard sequence $W_{M,n1}$; $\alpha_{n2}W_{M,n2}X_{n2}$,

which is obtained by multiplying the data X_{n2} of the gain α_{n2} and the orthogonal Hadamard sequence $W_{M,n2}$; a first adder 810 for outputting

$\sum_{n=1}^{K} (\alpha_{n1} W_{M,n1} X_{n1})$, which is obtained by summing the output signals from the first Hadamard sequence multiplier 600; a second adder 820 for outputting

$\sum_{n=1}^{K} (\alpha_{n2} W_{M,n2} X_{n2})$, which is obtained by summing the output signals from the second Hadamard sequence multiplier 700; a complex multiplier 900 for receiving the output signal from the first adder 810 and the output signal from the second adder 820 in the complex form of

$\sum_{n=1}^{K} (\alpha_{n1} W_{M,n1} X_{n1} + j\alpha_{n2} W_{M,n2} X_{n2})$ and complex multiplying the received signal by $W_{M,I}+jPW_{M,Q}$, which consist of the orthogonal Hadamard code $W_{M,I}$, and the permuted orthogonal Hadamard code $PW_{M,Q}$, wherein $W_{M,Q}$ and a predetermined sequence P are multiplied; a spreading unit 300 for multiplying the output signal from the complex multiplier 900 by a spreading code; a filter 400 for filtering the output signal from the spreading unit 300; and a modulator 500 for modulating the output signal from the filter 400 by multiplying the modulation carrier wave, summing the in-phase signal and the quadrature phase signal and outputting a real part of the modulated signal.

Additionally, in Fig. 9 the construction of the spreading unit 300, the filter 400 and the modulator 500 is the same as the embodiment of Fig. 4. However, in Fig. 9, the multiplication of the complex orthogonal Hadamard sequence is separated from the complex multiplier 100 through 100n and implemented in the rear portion of the summing

unit. The multiplication of each channel by the complex orthogonal Hadamard sequence is not implemented , and the summed signals of two groups are multiplied by the complex type orthogonal Hadamard sequence.

In the first orthogonal Hadamard sequence multiplier 600 $\alpha_{11}W_{M,11}X_{11}$, is obtained through multiplier 610, 611, 620, 621, 630, 631, 640 and 641 by multiplying first data X_{11} of the first group by the orthogonal Hadamard sequence $W_{M,11}$ and the gain α_{11}. Respectively, $\alpha_{21}W_{M,21}X_{21}$ is obtained by multiplying the second data X_{21} of the first group by orthogonal Hadamard sequence $W_{M,21}$ and the gain α_{21}. Additionally $\alpha_{n1}W_{M,n1}X_{n1}$ is obtained by multiplying the n-th data X_{n1} of the first group by orthogonal Hadamard sequence $W_{M,n1}$ and the gain α_{n1}.

The first adder 810 sums $\alpha_{n1}W_{M,n1}X_{n1}$ of each channel to output

$$\sum_{n=1}^{K}(\alpha_{11}W_{M,11}X_{11}).$$

In the second orthogonal Hadamard sequence multiplier 700, $\alpha_{12}W_{M,12}X_{12}$, is obtained through multiplier 720, 721, 730, 731, 740 and 741 by multiplying the first data X_{12} of the second group by the orthogonal Hadamard sequence $W_{M,12}$ and the gain α_{12}. Respectively, $\alpha_{22}W_{M,22}X_{22}$ is obtained by multiplying the the second data X_{22} of the second group by the Hadamard sequence $W_{M,22}$ and the gain α_{22}. Additionally, $\alpha_{n2}W_{M,n2}X_{n2}$ is obtained by multiplying the n-th data X_{n2} of the second group by the orthogonal sequence $W_{M,n2}$ and the gain α_{n2}.

The second adder 820 sums $\alpha_{n2}W_{M,n2}X_{n2}$ of each channel to output

$$\sum_{n=1}^{K}(\alpha_{n2}W_{M,n2}X_{n2}).$$

The signal outputted from the first adder 810 forms an in-phase data and the signal

outputted from the second adder 820 forms quadrature phase data.

In addition, the complex multiplier 900 receives the output signals in the complex form from the first and second adder 810 and 820 and multiplies the complex output signals

$$\sum_{n=1}^{K}(\alpha_{n1}W_{M,n1}X_{n1} + j\alpha_{n2}W_{M,n2}X_{n2})$$

from the first and second adders 810 and 820 by a complex signal of $W_{M,I}+jPW_{M,Q}$ that is comprised of an orthogonal Hadamard code $W_{M,I}$ and $PW_{M,Q}$, which results from the multiplication of the orthogonal Hadamard code $W_{M,Q}$ by the sequence P. P is a predetermined sequence, spreading code or integer configured so that two consecutive sequences have identical values. Accordingly, the complex output signals from the first and second adders 810 and 820 are complex-multiplied by the complex signals of $W_{M,I}+jPW_{M,Q}$ by the complex multiplier 900.

The spreading unit 300 multiplies the output signal from the complex multiplier 900 by the spreading code SCI and spreads the same. Thus, the spread signals are then filtered by the pulse shaping filters 410 and 420. The modulation carrier waves of $\cos(2\pi f_c t)$ and $\sin(2\pi f_c t)$ are multiplied by the modulation multipliers 510 and 520 thereby outputting s(t). In the following equation is obtained.

$$\left(\sum_{n=1}^{K}(\alpha_{n1}W_{M,n1}X_{n1}+j\alpha_{n2}W_{M,n2}X_{n2})\right) \times (W_{M,I}+jPW_{M,Q}) \times SC$$ where K represents an integer greater than or equal to 1.

Fig. 10 illustrates an embodiment where two channel data are complex-multiplied. Channel data X_{11} is allocated to the first orthogonal Hadamard sequence multiplier 600 and another channel data X_{12} is allocated to the second orthogonal Hadamard sequence multiplier 700.

As shown, the orthogonal Hadamard sequence multiplier includes the following: a first multiplier 610; a second multiplier 611; a third multiplier 710; and a fourth multiplier 711.

The complex multiplier 900 includes the following: fifth and sixth multipliers 901 and 902; seventh and eighth multipliers 903 and 904 multiplier 711 by the permutated; a first adder 905; and a second adder 906.

Therefore, the first and second multipliers 610 and 611 multiply the data X_{11} by the orthogonal Hadamard sequence $W_{M,11}$ and the gain α_{11} thereby outputting $\alpha_{11}W_{M,11}X_{11}$(=a). In addition, the third and fourth multipliers 710 and 711 multiply the data X_{12} by the orthogonal Hadamard sequence $W_{M,12}$ and the gain α_{12} thereby outputting $\alpha_{12}W_{M,12}X_{12}$(=b). The fifth and sixth multipliers 901 and 902 multiply $\alpha_{11}W_{M,11}X_{11}$(=a) and $\alpha_{12}W_{M,12}X_{12}$(=b) by the orthogonal Hadamard sequence $W_{M,I}$(=c) thereby generating $\alpha_{11}W_{M,11}X_{11}W_{M,I}$(=ac) and $\alpha_{12}W_{M,12}X_{12}W_{M,I}$(=bc). The seventh and eighth multipliers 903 and 904 multiply $\alpha_{11}W_{M,11}X_{11}$(=a) and $\alpha_{12}W_{M,12}X_{12}$(=b) by the permuted orthogonal Hadamard sequence $PW_{M,Q}$ thereby generating $\alpha_{11}W_{M,11}X_{11}PW_{M,Q}$(=ad) and $\alpha_{12}W_{M,12}X_{12}PW_{M,Q}$(=bd).

The first adder 905 outputs $(\alpha_{11}W_{M,11}X_{11}W_{M,I})-(\alpha_{12}W_{M,12}X_{12}PW_{M,Q})$ (=ac-bd). That is, $\alpha_{12}W_{M,12}X_{12}PW_{M,Q}$(bd) is subtracted from $\alpha_{11}W_{M,11}X_{11}W_{M,I}$(=ac). The second adder 906 generates $(\alpha_{11}W_{M,11}X_{11}PW_{M,Q})+(\alpha_{12}W_{M,12}X_{12}W_{M,I})$(=ad+bc). That is, $(\alpha_{11}W_{M,11}X_{11}PW_{M,Q})$(=ad) is summed by $(\alpha_{12}W_{M,12}X_{12}W_{M,I})$ (bc).

Fig. 10 illustrates the complex multiplier 900 shown in Fig. 9. For example, $\alpha_{11}W_{M,11}X_{11}$ is "a", $\alpha_{12}W_{M,12}X_{12}$ is "b", the orthogonal Hadamard sequence $W_{M,I}$ is "c", and the permuted orthogonal Hadamard sequence $PW_{M,Q}$ is "d".

Since (a+jb)(c+jd)=ac-bd+j(bc+ad), the signal from the complex multiplier 900 consists of the in-phase information ac-bd and the quadrature phase information bc+ad.

The in-phase and quadrature phase information is spread by the spreading unit 300 based on the spreading code (for example, PN code). In addition, the I channel signal, which is the in-phase information, and the Q channel signal, which is the quadrature phase information signal, are filtered by the first and second pulse shaping filters 410 and 420. The first and second multipliers 510 and 520 multiply the output signals from the first and second pulse shaping filters 410 and 420 by $\cos(2\pi f_c t)$ and $\sin(2\pi f_c t)$. The output signals from the multipliers 510 and 520 are summed by the adder 530 which outputs S(t).

The embodiment as shown in Fig. 9 is identical to Fig. 4 instead of orthogonal Hadamard sequence, Walsh code or other orthogonal code may be used. In addition, in the orthogonal Hadamard sequence of each channel, the sequence vector of the k-th column or row is set to W_{k-1} in the MxM Hadamard matrix. Preferably, $\alpha_{n1}W_0X_{n1}+j\alpha_{n2}W_{2p}X_{n2}$ and W_0+jPW_1 are complex-multiplied based on $W_{M,n1}=W_0$, $W_{M,n2}=W_{2p}$ (where p represents a predetermined number in a range from 0 to (M/2)-1, and $W_{M,I}=W_0$, $W_{M,Q}=W_1$. The orthogonal Hadamard sequence is allocated to each channel based on the above-described operation, and if other channels remain which are not allocated the orthogonal Hadamard sequence by the above-described operation then any row or column vector from the Hadamard matrix can be selected.

Fig. 11 illustrates an embodiment of a permuted orthogonal complex spreading apparatus with two input channels. In this case, the data of two channels, namely, the pilot channel and the data of traffic channels are multiplied by the gain and orthogonal Hadamard sequence. The two channel signals are then inputted into the complex

multiplier 900 in the complex form and the orthogonal Hadamard sequence of the complex form is multiplied by the complex multiplier 900.

Fig. 12 illustrates an embodiment of a permuted orthogonal complex spreading apparatus with three input channels. The pilot channel and signaling channel are allocated to the first orthogonal Hadamard sequence multiplier 700 and the traffic channel is allocated to the second orthogonal Hadamard sequence multiplier 700.

Fig. 13A illustrates an embodiment of a permuted orthogonal complex spreading apparatus with four input channels. In Fig. 13B, the system may be constructed so that the input data (traffic 1 and traffic 2) have identical gains ($\alpha_{31}=\alpha_{12}$).

Fig. 14A and 14B illustrate an embodiment of a permuted orthogonal complex spreading apparatus with five input channels.

In Fig. 14B, when the data (Traffic) is separated into two channel data (Traffic 1) and (Traffic 2) and then is inputted, the gains adapted to each channel are identical ($\alpha31=\alpha12$).

Fig. 15A is a phase trajectory view of an OCQPSK, according to the present invention. Fig. 15B is a phase trajectory view of a POCQPSK, according to the present invention. Fig. 15C is a phase trajectory view of a complex spreading method, according to PN complex spreading method of the prior art.

The shapes of the trajectories around the zero point are different when comparing Figs. 15A, 15B and 15C. This difference indicates the difference between the three methods.

Fig. 7 illustrates a statistical distribution of a peak power-to-average power ratio of the CDMA ONE method compared to the OCQPSK and POSQPSK methods.

In order to provide the identical condition the following has to occur: power level of the signal channel is controlled to be the same as the power level of the communication channel; power level of the pilot channel is controlled to be lower than the power level of the communication channel by 4dB.

In the case of the POCQPSK, in the first block 600 of Fig. 9, $W_{M,11}=W_0$, and $W_{M,21}=W_2$ are implemented and in the second block 700 $W_{M,12}=W_4$, and $W_{M,I}=W_0$ and $W_{M,Q}=W_1$ are implemented. For the value of P, the spreading code is used so that two consecutive sequences have an identical value.

For example, the probability that the instantaneous power exceeds the average power value (0dB) by 4dB is 0.1% based on POCQPSK, and the complex spreading method is 2%. Therefore, in view of the power efficiency, the method in accordance with the present invention, is a new modulation method having excellent characteristics.

As described above, in the OCQPSK in accordance with the present invention, the first data and the second data are multiplied by the gain and orthogonal code, and the resultant values are complex-summed, and the complex summed value is complex-multiplied by a complex type orthogonal code. A method is utilized where the information of the multichannel of the identical structure is summed and then spread. Therefore, this method statistically reduces the peak power-to-average power ratio to the desired range.

Additionally, in the POCQPSK the data of the first block and the data of the second block are multiplied by the gain and the orthogonal code, respectively, and the permuted orthogonal spreading code of the complex type is complex-multiplied and then spread. Therefore, this method statistically reduces the peak power-to-average power ratio to the

desired range. Utilizing the combined orthogonal Hadamard sequence, it is possible to decrease the phase dependency based in multichannel and multi-user interference.

Although, the preferred embodiments of the present invention have been disclosed for illustrative purposes those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as recited in the accompanying claims.